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(54) **Work machine with steering control**

(57) A work machine (10) with steering control has a first means (16) for moving the work machine and a first means (14) for transmitting power to the first means for moving. The work machine also has a second means (16) for moving the work machine and a second means (14) for transmitting power to the second means for moving. The work machine further has a power source

(12) configured to drive the first and second means for transmitting power. The work machine has a sensor (28) configured to generate a signal indicative of work machine maneuvering. The work machine further has a means (26) for controlling an output of the power source (12) in response to the input indicative of work machine maneuvering.

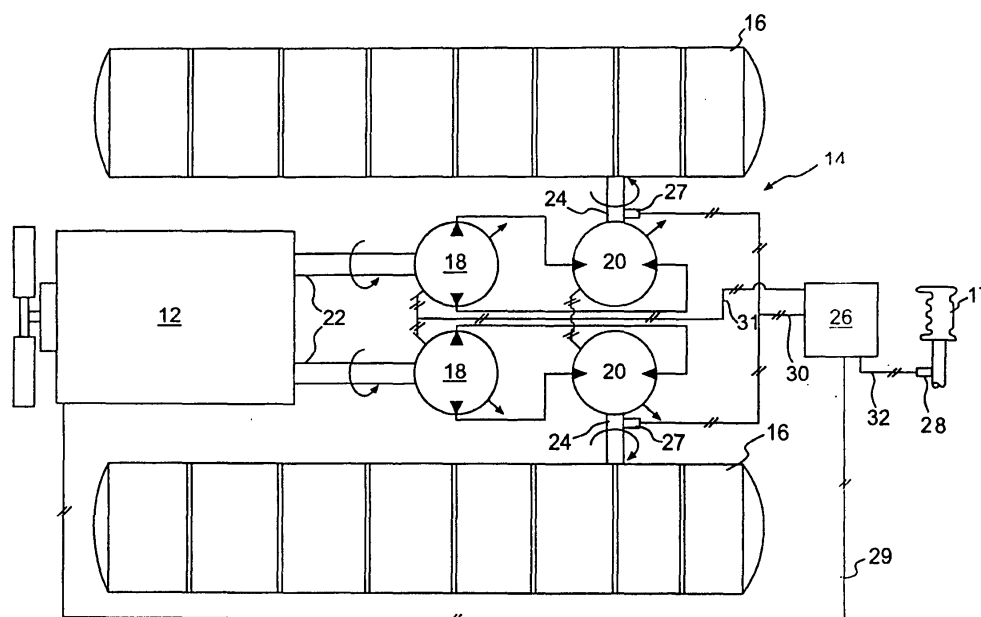


FIG. 2

Description

Technical Field

[0001] The present invention relates generally to a work machine, and more particularly to a work machine having steering control.

Background

[0002] Work machines, including track-type tractors such as the D5 made by Caterpillar Inc., track-type loaders such as the 963 made by Caterpillar Inc., skid-steer loaders, hydraulic tracked excavators, military tanks, and other types of heavy machinery, are used for a variety of tasks. These work machines may include ratio control devices that transmit torque from an engine to one or more traction devices that move the work machine. These ratio control devices may include a hydrostatic transmission, an electric transmission, a mechanical transmission, or any other type of transmission known in the art. The engine may include a diesel engine, a gasoline engine, a natural gas engine, or any other engine configured to operate at a range of output speeds.

[0003] The traction devices may be independently manipulated to steer the work machine. For example, during a steering event, a brake may be applied to one or more of the traction devices located on one side of the work machine to allow one or more driven traction devices on the other side of the work machine to turn the work machine. Alternately, one or more driven traction devices located on one side of the work machine may be caused to rotate at a slower speed than or in a direction opposite to one or more driven traction devices located on the opposite side of the work machine to cause the work machine to turn.

[0004] Turning a work machine, by any of these methods, may require more torque from the ratio control devices than when the work machine travels in a straight direction. A ratio control device designed for efficiently propelling the work machine in a straight direction may not also have the torque capacity for efficiently turning the work machine at a given speed. Further, a ratio control device designed for efficiently turning the work machine at a given speed may be too large to efficiently propel the work machine in a straight direction.

[0005] U.S. Patent No. 6,654,676 (the '676 patent) is issued to Nakagawa et al. on 25 November 2003, describes a steering system for a track-laying vehicle that attempts to account for the different torque requirements of turning and straight-line moving of a work machine. The '676 patent describes a steering system that includes an engine connected to a torque converter, which is connected to a transmission. The transmission is connected to a transverse shaft through a bevel gear that is coupled to right and left planetary gear mechanisms, each of the right and left planetary gear mecha-

nisms being connected to sprockets. The '676 patent also describes a pump and a fixed displacement motor, the motor being coupled to the planetary gear mechanisms.

[0006] When a traveling lever in the steering system of the '676 patent is manually operated to cause a pivot turn of the vehicle, a brake is applied to one of the traction devices and the pump and motor are actuated to apply driving force to the planetary gear mechanisms. Simultaneously, the speed of the engine is reduced to prevent over-speed of the pump and motor. After the turn is complete, the driving force from the motor is interrupted from driving the planetary gear mechanisms.

[0007] While the steering system of the '676 patent may offer some improved efficiencies during a pivot turn, the steering system of the '676 patent may not provide any assistance during other types of turns. In addition, the torque converter, transmission, and planetary gear mechanism arrangement may be complex and costly.

[0008] The present invention is directed to overcoming one or more of the problems set forth above.

Summary of the Invention

[0009] In one aspect, the present disclosure is directed to a work machine with steering control. The work machine includes a first traction device and a first ratio control device operatively connected to the first traction device. The work machine also includes a second traction device and a second ratio control device operatively connected to the second traction device. The work machine further includes a power source configured to drive the first and second ratio control devices. The work machine further includes a sensor configured to generate a signal indicative of work machine maneuvering. The work machine further includes a controller in communication with the power source. The controller is operable to control an output of the power source in response to the signal indicative of work machine maneuvering.

[0010] In another aspect, the present disclosure is directed to a method of operating a work machine having a power source. The method includes driving a first ratio control device that is operatively connected to a first traction device, and driving a second ratio control device that is operatively connected to a second traction device. The method also includes receiving an input indicative of work machine maneuvering. The method further includes controlling an output of the power source in response to the input indicative of work machine maneuvering.

Brief Description of the Drawings

[0011]

Fig. 1 is a diagrammatic illustration of a work machine according to an exemplary embodiment of the

present invention;

Fig. 2 is a diagrammatic illustration of a power system for a work machine according to an exemplary embodiment of the present invention;

Fig. 3 is a flowchart illustrating a method of operating a work machine according to an exemplary embodiment of the present invention; and

Fig. 4 is a graph illustrating a relationship between work machine travel speed, a directional change request, and a desired power source speed for a work machine according to an exemplary embodiment of the present invention.

Detailed Description

[0012] Fig. 1 illustrates an exemplary embodiment of a work machine 10 having a power source 12 and a transmission 14. Transmission 14 may be connected to a plurality of traction devices 16 (only one shown in Fig. 1) controlled by a steering device 17. Power source 12 may be an engine such as, for example, a diesel engine, a gasoline engine, a natural gas engine, or any other engine apparent to one skilled in the art. Power source 12 may also include other sources of power such as a fuel cell, a power storage device, or any other source of power known in the art. Transmission 14 may be a hydrostatic transmission, an electric transmission, a mechanical transmission, a hydro-mechanical transmission or any other means for transmitting power from a power source to a traction device. Traction devices 16 may include tracks, belts, wheels, tires, or any device for moving the work machine. Steering device 17 may include one or more of a steering wheel, a joystick, a lever, a pedal, or any other device for steering the work machine.

[0013] As illustrated in Fig. 2, transmission 14 may be connected to power source 12 and may include two pumps 18 fluidly connected to two motors 20 in a dual-path configuration. Pumps 18 and motors 20 may be variable displacement, variable delivery, fixed displacement, or any other configuration known in the art. Each of pumps 18 may be directly connected to power source 12 via an input shaft 22. Alternately, pumps 18 may be connected to power source 12 via a torque converter, a gear box, or in any other manner known in the art. Transmission 14 may also include an output shaft 24 connecting each motor 20 to one of traction devices 16. Work machine 10 may or may not include a reduction gear arrangement such as, for example, a planetary arrangement disposed between each motor 20 and the associated traction device 16.

[0014] Work machine 10 may include a controller 26, one or more transmission output speed sensor 27, and a steering sensor 28. Each speed sensor 27 may be proximally disposed relative to output shaft 24 and configured to generate a signal indicative of the rotational speed of output shaft 24 that corresponds to a work machine travel speed. Alternately, speed sensor 27 may be

proximally disposed relative to traction device 16, or may be in any other location for generating a signal that corresponds to work machine travel speed. Sensor 28 may be proximally disposed relative to steering device 17 and configured to generate a signal indicative of a requested work machine directional change as input by an operator. Controller 26 may be in communication with power source 12, speed sensors 27, variable displacement pumps 18 and motors 20, and sensor 28 via control lines 29, 30, 31, and 32, respectively. Control lines 29, 30, 31, and 32 may be digital, analog, or mixed types of communication lines. Alternately, communication with the various components may be implemented by means of mechanical or hydraulic lines.

[0015] Controller 26 may include all the components required to run an application such as, for example, a memory, a secondary storage device, and a central processing unit. Controller 26 may, however, contain additional or different components such as, for example, mechanical or hydro-mechanical devices. Various other known circuits may be associated with controller 26 such as, for example, power supply circuitry, signal-conditioning circuitry, solenoid driver circuitry, and other appropriate circuitry.

[0016] Fig. 3 is a flow chart 34 describing a method of operating work machine 10. Fig. 4 is a graph 36 that illustrates an exemplary power source map exercised by controller 26 for correlating a work machine travel speed, work machine maneuvering, and a desired power source speed. These figures will be discussed in the following section to further illustrate the disclosed system and its operation.

Industrial Applicability

[0017] The disclosed system may be applicable to any work machine that changes direction by manipulating a speed and/or a torque applied to one or more traction devices. Examples may include a track-type tractor, a track-type loader, a skid-steer loader, a hydraulic-tracked excavator, a military tank, or any other work machine known in the art that utilizes independent traction control for steering.

[0018] As described above, changing the direction of a typical work machine may require large amounts of torque from the ratio control devices. Specifically, the torque from the pump 18 and motor 20 that propels an outside (relative to the curvature of the turn) traction device 16 may be significantly greater during a turning operation than when the work machine travels in a straight direction. The disclosed work machine 10 may account for these differences by varying power source speed and/or the displacement of pumps 18 and motors 20 during a directional change. For example, proportionately increasing power source speed, and decreasing the output ratio of the pump 18 and motor 20 associated with the outside traction device 16 increases the torque capacity of transmission 14 without changing the result-

ing speed of the outside traction device 16. Independently changing an output ratio of transmission 14 may or may not affect the output speed of power source 12. This increased torque capacity of motor 20 associated with the outside traction device 16 may facilitate full or partial utilization of a regenerative braking power that the pump 18 and motor 20 associated with an inside traction device 16 absorb during execution of the requested turning operation. Therefore, a smaller (lower corner power), lower cost transmission 14 that efficiently propels the work machine in a straight direction can also provide the torque for performing efficient turning operations. Such smaller transmissions, in addition to being a lower cost, may produce less heat and require less cooling capacity than their larger (higher corner power) counterparts.

[0019] The directional change control strategy of work machine 10 will now be explained in detail. As outlined in flow chart 34 of Fig. 3, a method of operating work machine 10 during a turning event begins at step 100. At step 110, controller 26 senses the work machine travel speed via speed sensor 27. At step 120, which may or may not occur simultaneously with step 110, controller 26 monitors work machine maneuvering.

[0020] Work machine maneuvering may be monitored in several ways. Work machine maneuvering may be monitored by comparing an indicated travel speed from sensor 27 located on one side of work machine 10 with another sensor 27 located on an opposite side of work machine 10. The difference in travel speeds between opposite sides of work machine 10 may be indicative of the severity of a turn radius initiated during maneuvering of work machine 10. The difference in travel speeds may also be determined by monitoring command speed signals sent to transmission 14. Work machine maneuvering may also be monitored by sensing operator input to steering device 17. A work machine operator may manipulate steering device 17 to indicate a requested change in work machine direction. In response to the operator input to steering device 17 (i.e., a requested directional change), sensor 28 may send a signal via communication line 32 to controller 26, indicative of the requested directional change.

[0021] At step 140, controller 26 may determine a desired power source speed and associated minimum and maximum power source speed set points required to efficiently maneuver the work machine. Controller 26 may compare the sensed work machine travel speed and the value of the work machine maneuvering signal generated in step 120 with a map stored within a memory of work machine 10 to determine a desired power source speed. Alternately, a desired work machine travel speed as input by an operator and the value of the work maneuvering signal may be compared with the map to determine the desired power source speed. The map may be in the form of a look-up table, one or more equations, or another form for storing information.

[0022] An example of such a map is illustrated in

graph 36 of Fig. 4. Work machine travel speed is plotted along one axis of graph 36. The travel speed axis is split between a forward and reverse direction at a center point of zero kilometers per hour, and extends to the left and right in increasing speeds of opposite travel directions. Work machine maneuvering is plotted along another axis of graph 36, with the turn radius of the work machine increasing from back to front of graph 36. Using the sensed work machine travel speed and the value of the work machine maneuvering signal, a desired power source speed may be determined based on a projection onto a contoured surface of graph 36. The desired power source speed is one that may efficiently maneuver the work machine.

[0023] For example, a forward travel speed may be sensed during step 110 and represented as a line 37a on graph 36. The turn radius value of the work machine maneuvering signal sensed in step 120 may be represented as a line 37b on graph 36. Extending a line in the desired power source speed axis direction from the intersection of lines 37a and 37b to the contoured surface of graph 36 determines the desired power source speed 37c, as shown in Fig. 4. For certain travel speed values, a decreasing turning radius will also result in an increasing desired power source speed.

[0024] After determining a desired power source speed, minimum and maximum power source speed set points may be determined as offsets from the desired power source speed. For example, offsets δ_1 and δ_2 may be added and/or subtracted from the desired power source speed 37c, determined in the above example, to determine maximum and minimum power source speed set points:

$$\text{Set Point}_{\text{Max}} = 37c + \delta_1 \quad \text{Set Point}_{\text{Min}} = 37c - \delta_2$$

[0025] It is contemplated that the offset used to determine the minimum power source speed set point may or may not be the same as the offset used to determine the maximum power source speed set point. It is also contemplated that the minimum and maximum power source speed set points may be determined as other functions of the desired power source speed. One of the minimum and maximum power source speed set points may also be determined as a function of the other. In addition, the power source speed set points may be determined directly, in a manner similar to that described above for determining the power source speed, without determining the desired power source speed. The desired power source speed and/or set points may also be determined as functions of parameters other than machine operating and maneuvering parameters.

[0026] After the desired power source speed and associated set points are determined, control continues in step 150 with closed loop speed control. Although a desired power source speed has been determined, the minimum and maximum power source speed set points

may actually drive the closed loop speed control. The minimum and maximum set points essentially create a zone of acceptable tolerance around the desired power source speed, and the closed loop speed control may change operating parameters of the power source and/or transmission 14 until the power source speed is within the tolerance zone. For example, if the current power source speed is below the minimum set point, operating parameters of the power source 12 and/or transmission 14 may be changed to increase the power source speed. If the current power source speed is above the maximum set point, operating parameters of the power source 12 and/or transmission 14 may be changed to decrease the power source speed. Controller 26 continuously monitors power source speed and adjusts the power source operating parameters and/or transmission parameters when the power source speed deviates from the tolerance zone set by the minimum and maximum set points.

[0027] It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed work machine steering control system without departing from the scope of the invention. Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope of the invention being indicated by the following claims and their equivalents.

Claims

1. A work machine (10), comprising:

a first means (16) for moving the work machine;
a first means (14) for transmitting power to the first means for moving;
a second means (16) for moving the work machine;
a second means (14) for transmitting power to the second means for moving;
a power source (12) configured to drive the first and second means for transmitting power;
a sensor (28) configured to generate a signal indicative of work machine maneuvering; and
a means (26) for controlling an output of the power source in response to the signal indicative of work machine maneuvering.

2. The work machine of claim 1, wherein the means for controlling an output of the power source is also a means for controlling a speed ratio of at least one of the first and second means for transmitting power in response to the signal indicative of work machine maneuvering.

3. The work machine of claim 2, wherein controlling a

speed ratio of at least one of the first and second means for transmitting power changes the output of the power source.

4. The work machine of claim 1, further including a second sensor (27) configured to generate a signal indicative of a work machine operating parameter, wherein the means for controlling is operable to control an output of the power source in further response to the signal indicative of a work machine operating parameter.

5. The work machine of claim 1, further including a means (17) for steering the work machine, wherein the signal indicative of work machine maneuvering is responsive to operator input to the means for steering.

6. A method of operating a work machine having a power source, comprising:

driving a first ratio control device (14) that is operatively connected to a first traction device (16);
driving a second ratio control device (14) that is operatively connected to a second traction device (16);
receiving an input (28) indicative of work machine maneuvering; and
controlling an output of the power source in response to the input indicative of work machine maneuvering.

7. The method of claim 6, further including controlling a speed ratio of at least one of the first and second ratio control devices in response to the signal indicative of work machine maneuvering.

8. The method of claim 7, wherein controlling a speed ratio of at least one of the first and second ratio control devices changes the output of the power source.

9. The method of claim 6, further including receiving an input (27) indicative of a work machine operating parameter, wherein the step of controlling an output of the power source is further in response to the input indicative of a work machine operating parameter.

10. The method of claim 6, wherein controlling an output of the power source includes:

calculating a desired output of the power source;
determining a desired output range of the power source; and
changing an output of the power source when

the output of the power source is outside of the desired output range.

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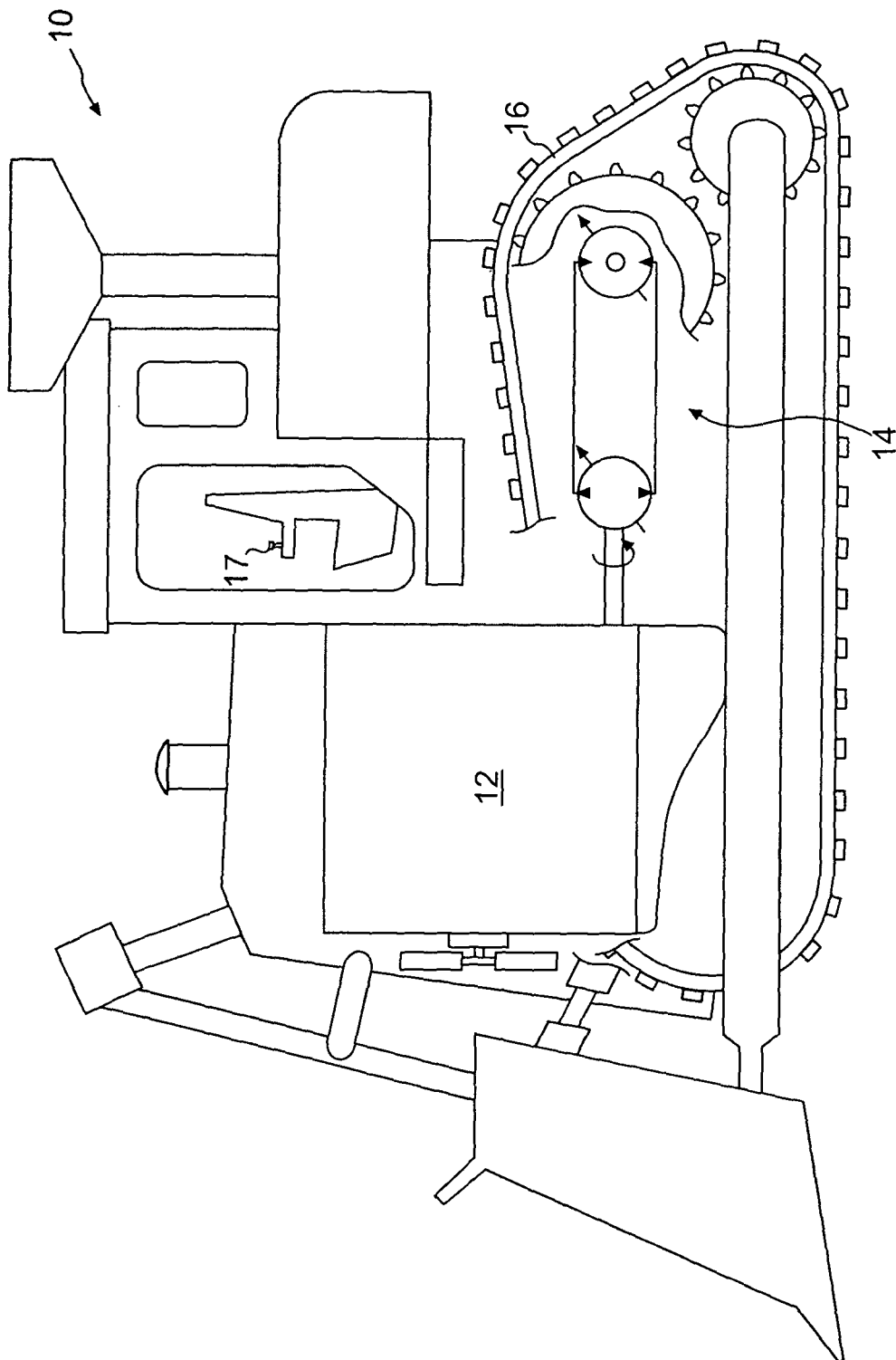


FIG. 1

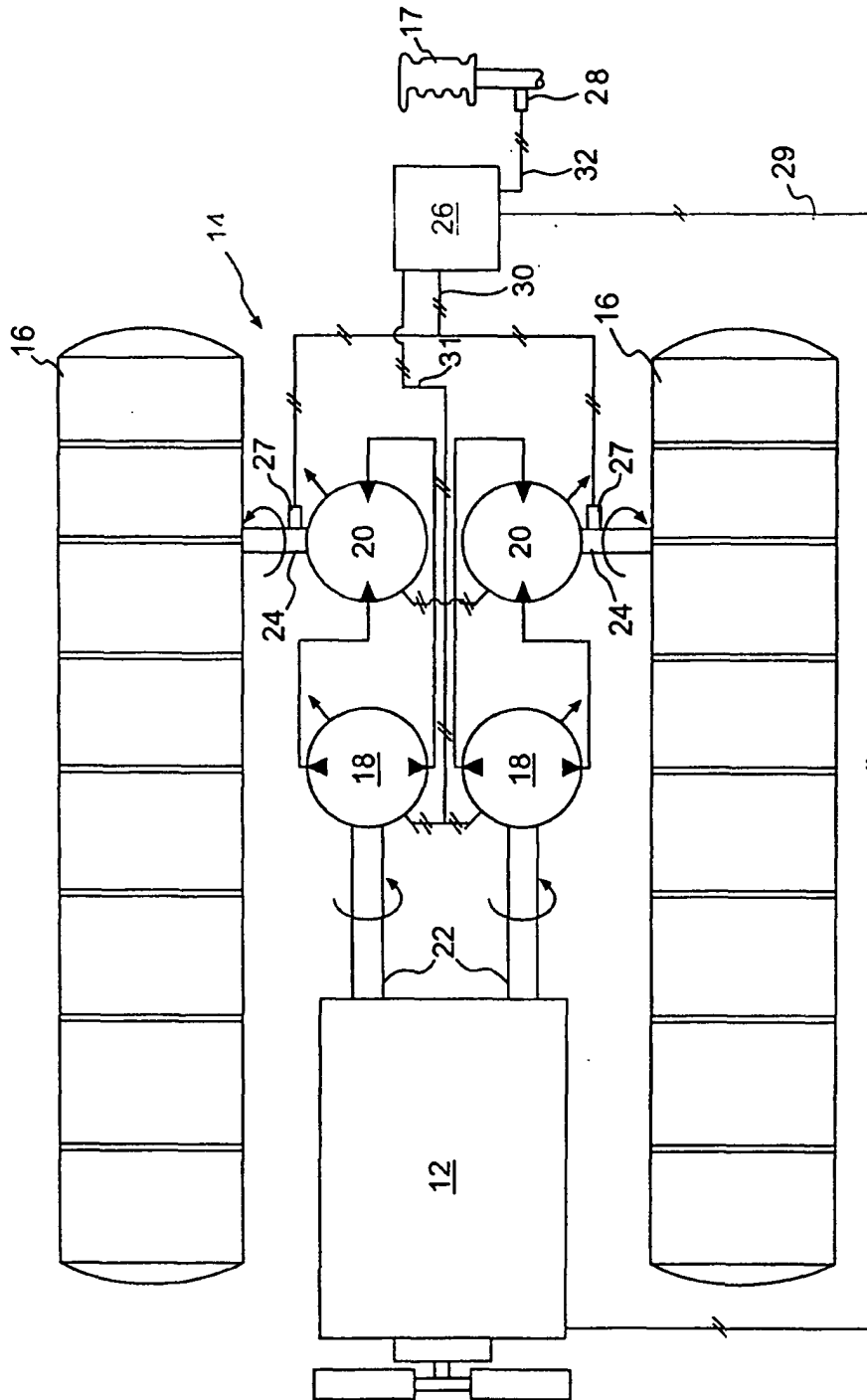
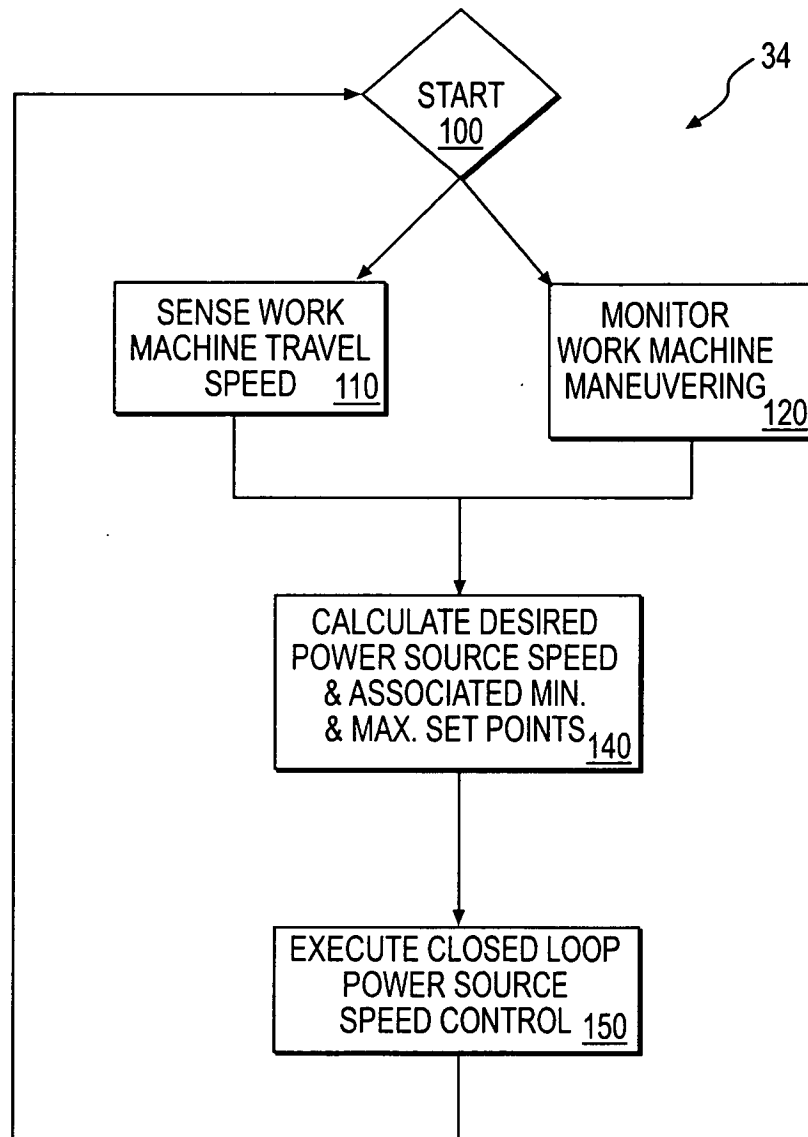


FIG. 2

**FIG. 3**

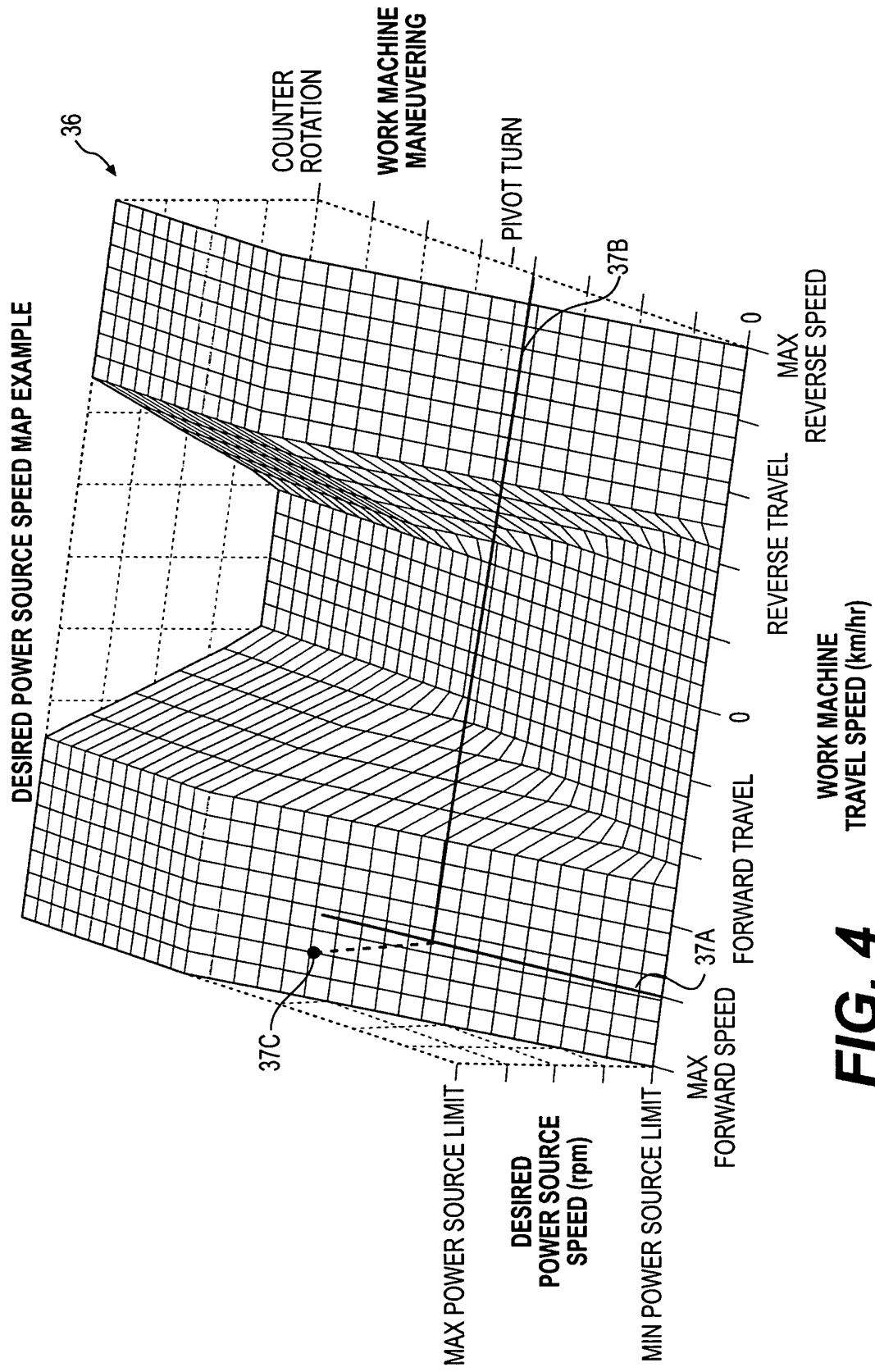


FIG. 4



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 00 4642

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The present search report has been drawn up for all claims			
Place of search Berlin		Date of completion of the search 27 April 2005	Examiner Wiberg, S
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 04 00 4642

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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